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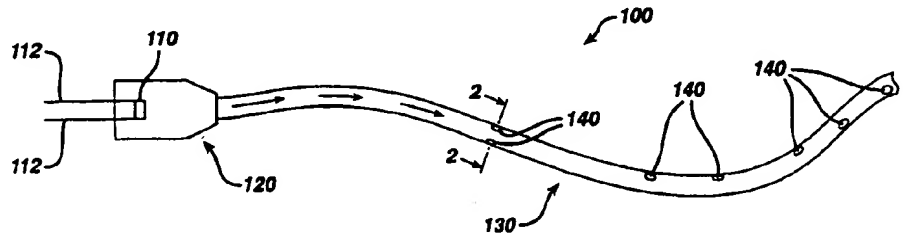
(54) Title: DECORATIVE LIGHTING APPARATUS WITH LIGHT SOURCE AND LUMINESCENT MATERIAL



(57) Abstract

An exemplary lighting apparatus (100) comprises a light source (110) such as an LED, a transmissive body (130) optically coupled to the light source (110), and at least one region of luminescent material (140) formed on a portion of the transmissive body (130), the at least one region of luminescent material (140) forming an ornamental design on the transmissive body (130), wherein the at least one region of luminescent material (140) absorbs light having a first spectrum transmitted through the transmissive body (130) and emits light having a second spectrum outside of the transmissive body (130). The lighting apparatus (100) can be used in a decorative manner, such as for holiday lighting or as a display. The ligthing apparatus (100) can he used to display a variety of patterns and shapes and can operate safely a low power over a long lifetime.

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(54) Title: DECORATIVE LIGHTING APPARATUS WITH LIGHT SOURCE AND LUMINESCENT MATERIAL

(54) Titre: APPAREIL D'ECLAIRAGE DECORATIF COMPORTANT UNE SOURCE LUMINEUSE ET UNE MATIERE LUMINESCENTE

(57) Abstract

An exemplary lighting apparatus (100) comprises a light source (110) such as an LED, a transmissive body (130) optically coupled to the light source (110), and at least one region of luminescent material (140) formed on a portion of the transmissive body (130), the at least one region of luminescent material (140) forming an ornamental design on the transmissive body (130), wherein the at least one region of luminescent material (140) absorbs light having a first spectrum transmitted through the transmissive body (130) and emits light having a second spectrum outside of the transmissive body (130). The lighting apparatus (100) can be used in a decorative manner, such as for holiday lighting or as a display. The ligthing apparatus (100) can be used to display a variety of patterns and shapes and can operate safely a low power over a long lifetime.

(57) Abrégé

L'invention concerne un modèle d'appareil d'éclairage (100) qui comprend une source lumineuse (110), telle qu'une diode électroluminescente, un corps transmissif (130) couplé par voie optique à la source lumineuse (110), et au moins une zone faite d'une matière luminescente (140) située sur une partie du corps transmissif (130). Cette zone de matière luminescente (140) forme un dessin décoratif sur le corps transmissif (130). La zone de matière luminescente (140) absorbe la lumière ayant un premier spectre et transmise à travers ledit corps (130), puis émet une lumière ayant un second spectre hors dudit corps (130). L'appareil d'éclairage (100) peut être utilisé à des fins décoratives, tel qu'un éclairage festif ou un affichage. Cet appareil (100) peut en outre être utilisé pour afficher divers motifs et formes, et fonctionne sans danger à basse puissance pendant une longue durée.

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Description

DECORATIVE LIGHTING APPARATUS WITH LIGHT SOURCE AND LUMINESCENT MATERIAL

BACKGROUND

Field of the Invention

The present invention relates generally to decorative lighting, and more particularly to a lighting apparatus which includes a light source and a luminescent material which absorbs light from the light source and emits light of a different color.

Description of the Related Art

Examples of decorative lighting are numerous. U.S. Patent No. 5,649,755, for example, discloses an elongated, decorative, flexible, light-transmitting assembly, useful for adorning wearing apparel, which includes a source of light having a light-transmitting area. A length of clear flexible polymer has a first end adjacent the light transmitting area and an elongated body having an outer surface and a remote end. The length has many marks formed inwardly from the outer surface to cause the light entering the first end to be reflected in an attractive manner.

Another example of decorative lighting is disclosed in U.S. Patent No. 5,752,337. This patent discloses a multi-color illuminated panel made up of a decorative frontsheet having windows cut therein, a transparent supporting sheet, which may also have decorative printing thereon, and a pre-wired backsheet on which are affixed discrete individual single-color electro-luminescent light panel segments. The electro-luminescent light segments may have different colors and are arranged to shine through the windows and provide a multi-color lighting effect.

U.S. Patent No. 5,639,157 discloses a decorative string lighting system which includes a plurality of illuminators, a power cord for connection to a source of electrical power, and a wire harness for feeding the power to the illuminators. The system can also include a multiplicity of light output transducers, a control circuit powered from an external source for activating the transducers, the transducers of an illuminator subset being in separate circuit paths for independent activation by the control circuit, a translucent illuminator body, a fiber-optic element, one end of the element being optically connected to the illuminator body, and a coupler member optically connected to an opposite end of the fiber optic element, the coupler member being formed for receiving light from the illuminator subset and transmitting the light into the fiber optic element for lighting the illuminator body, means for producing spectrally distinct light from each transducer of the illuminator subset, whereby the illuminator body is lighted in colors corresponding to activated ones of the transducers of the coupler subset.

Although the above examples of decorative lighting are satisfactory, it would be desirable to have a decorative lighting apparatus which was simple in design, and which provided enhanced flexibility in emitting light of desired colors at selected locations in desired patterns.

SUMMARY

An exemplary lighting apparatus comprises a light source, a transmissive body optically coupled to the light source, and at least one region of luminescent material formed on a portion of the transmissive body, the at least one region of luminescent material forming an ornamental design on the transmissive body, wherein the at least one region of luminescent material absorbs light having a first spectrum transmitted through the transmissive body and emits light having a second spectrum outside of the transmissive body. The lighting apparatus can be used in a decorative manner, such as for

holiday lighting or as a display. The lighting apparatus can be used to display a variety of patterns and shapes and can operate safely at a low power over a long lifetime.

BRIEF DESCRIPTION OF THE DRAWINGS

Other features and advantages of the invention will be apparent from the following detailed description and the accompanying drawings, in which:

Figure 1 illustrates a lighting apparatus having a light source and a transmissive body according to one embodiment of the invention;

Figure 2 illustrates a cross section of the transmissive body of Figure 1;

Figure 3 illustrates a lighting apparatus having a light source and a plurality of transmissive bodies according to another embodiment of the invention; and

Figure 4 illustrates a lighting apparatus having a plurality of light sources and a transmissive body in the form of a thin strip according to another embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 illustrates a lighting apparatus according to one embodiment of the invention. The lighting apparatus 100 includes a light source 110 powered via electrical connectors 112, an optical coupler 120, a transmissive body 130, and at least one region of luminescent material 140.

The light source 110 typically comprises a light emitting diode (LED) or a laser diode. For example, the light source may comprise an LED or a laser diode which emits ultraviolet (UV) or blue light. Such LEDs and laser diodes are available commercially from Nichia Industrial Chemicals Ltd. in Japan.

Examples of LEDs which emit blue or UV radiation are described in U. S. Patent Nos. 5,813,752 and 5,813,753. Examples of laser diodes which emit blue or UV radiation are described in U.S. Patent Nos. 5,604,763 and 5,644,584. See also Shuji Nakamura and Gerhard Fasol, "The Blue Laser Diode" (1997).

The light source 110 can be optically coupled to the transmissive body 130 by an optical coupler 120. The optical coupler 120 may be in the shape of a truncated cone such that substantially all the radiation emitted from the light source 110 is coupled into the transmissive body 130. The optical coupler 120 and the transmissive body are preferably transparent in the wavelengths emitted by the light source 110. Typically, the optical coupler 120 and the transmissive body 130 are formed of a flexible material such as a polymer (e.g. epoxy or thermoplastic), a silicone, or a glass. For example, a polymer material having a thickness on the order of 1 mm may be flexible enough to bend with a radius of curvature of 1 mm or less without damage to the material. The optical coupler and transmissive body can be formed integrally as a single piece, in which case the optical coupler is merely the end portion of the transmissive body.

The lighting apparatus 100 is typically configured such that substantially all the light from the light source 110 is transmitted through the transmissive body 130 by total internal reflection. The transmissive body 130 can be a fiber optic cable, for example, through which the light from the light source propagates by total internal reflection.

Formed on the transmissive body 130 is at least one, and typically a plurality of regions of luminescent material 140. Typically, the luminescent material comprises an inorganic phosphor, as will be described below. However, other types of luminescent materials such as organic luminescent materials and dyes can be used in conjunction with exemplary embodiments of the invention.

In operation, the light source 110 generates light of a certain spectrum which is coupled to the transmissive body 130 through the optical coupler 120. The light propagates through the transmissive body until it is incident on one of the phosphor regions 140. The phosphor region 140 absorbs some fraction of the light from the light source which has a first spectrum and emits light of a different spectrum which is directed outside of the transmissive body 130 to produce a decorative effect.

The phosphor regions are typically decorative or ornamental in nature. The phosphor regions can be formed in any desired shape, pattern, or ornamental design. For example, as shown in Figure 1, the phosphor regions may comprise a plurality of discrete circular regions which are distributed along the length of the fiber optic cable. The phosphor regions may also comprise other shapes or patterns such as diamonds, helixes, ellipses, letters, numbers, or any other pattern or design, whether simple or elaborate. Typically, the phosphor regions cover only a portion of the surface of the transmissive body, rather than the entire surface of the transmissive body.

The phosphor regions may have different compositions to produce different colors when irradiated by radiation from the light source. For example, the following phosphors can be used with a UV light source:

Phosphor	Emitting Color
$(Sr,Ba,Ca)_5(PO_4)_3Cl:Eu^{2+}$	blue
$BaMg_2Al_{16}O_{27}:Eu^{2+}$	blue
$BaMgAl_{10}O_{17}:Eu^{2+}$	blue
$Ca_8Mg(SiO_4)_4Cl_2:Eu^{2+},Mn^{2+}$	green

$Ba_2SiO_4:Eu^{2+}$	green
$Ba_2(Mg,Zn)Si_2O_7:Eu^{2+}$	green
$(Ba,Sr)Al_2O_4:Eu^{2+}$	green
$Y_2O_3:Bi^{3+},Eu^{3+}$	red

The following phosphors can be used with a blue light source:

Phosphor	Emitting Color
$Y_3Al_5O_{12}$-Ce^{3+}	yellow
$Ba_2MgSi_2O_7:Eu^{2+}$	yellow
$Ba_2SiO_4:Eu^{2+}$	yellow
$SrS:Eu^{2+}$	red
$SrY_2S_4:Eu^{2+}$	red
$CaLa_2S_4:Ce^{3+}$	red
(Ca,Sr)S	red
$(Sr,Ca,Ba)(Al,Ga)_2S_4:Eu^{2+}$	green

Combinations of the above phosphors can be used to produce white light. For example, with a blue light source, $Y_3Al_5O_{12}$-Ce^{3+} can be combined with one of SrS:Eu^{2+}; SrY_2S_4:Eu^{2+}; and $CaLa_2S_4$:Ce^{3+} to produce white light. (Ca,Sr)S can be combined with (Sr,Ca,Ba)$(Al,Ga)_2S_4$:Eu^{2+} to produce white light. With a UV light source, a combination of the listed red, green, and blue phosphors can be used to produce white light. Other colors can be produced with appropriate combinations of phosphors, as will be recognized by those skilled in the art.

The phosphor regions can be formed in a number of ways. According to one embodiment, the phosphor regions are deposited directly onto portions of the surface of the transmissive body. The light propagating through the transmissive body which is incident on the phosphor regions is converted in wavelength and directed out of the transmissive body. Directly depositing the phosphor regions on the surface of the transmissive body provides the advantage of ease of manufacturing.

According to other embodiments, the phosphor regions are formed on indentations on the transmissive body. For example, Figure 2 shows a cross section of the transmissive body 130 of Figure 1 which includes three indentations upon which three phosphor regions 140 are formed. The indentations can be spherical in shape, for example, or can have flat surfaces like a notch. The phosphor regions can also be formed on a roughened surface which acts to scatter light propagating down the transmissive body 130.

Typically, the indentation, notch, or roughened surface upon which the phosphor is deposited projects into the transmissive body. For example, as shown in Figure 2, the indentations project into the fiber optic cable. In this way, the indentations provide a larger surface upon which light propagating through the transmissive body is incident. These embodiments may provide the advantage that more light propagating through the transmissive body is absorbed by the phosphor regions, making them appear brighter.

According to another embodiment of the invention, the phosphor regions can be formed around a sharp bend, e.g. 90-135°, in the fiber optic cable or transmissive body. The bend in the transmissive body scatters the light propagating therethrough onto the phosphor region formed on the bend which converts the light to a different color.

According to other embodiments, a splice region is formed in the transmissive body to scatter light. For example, two pieces of fiber optic cable can be spliced together such that the splice region scatters light propagating therethrough. A phosphor region is applied to the surface of the transmissive body around the splice region to absorb the light scattered by the splice region and to convert the light to a different spectrum and transmit the light outside of the transmissive body. The phosphor region can also be sandwiched in the splice region between the two pieces of fiber optic cable.

To prevent light from escaping from the transmissive body, a reflective or blocking coating can be applied to the outer surface of the transmissive body between the phosphor regions. The coating may comprise, for example, a reflective metal such as aluminum or silver applied by evaporation, or a reflective multilayer dielectric film such as SiO_2/TiO_2. The coating may itself be covered on the outside by a paint of an appropriate color, e.g. green for holiday decorations. The coating and paint layer can protect the transmissive body from physical damage, enhance the contrast between the phosphor regions and non-phosphor regions by eliminating scattered light between phosphor regions, and prevent UV light from escaping from the transmissive body.

Figure 3 illustrates a lighting apparatus according to another embodiment of the invention. The lighting apparatus 300 includes a light source 310, a plurality of transmissive bodies 330, and a plurality of phosphor regions 340. The light source 310 may be an LED or a laser diode, for example. The transmissive bodies 330 may comprise fiber optic cables which transmit the light by total internal reflection. The phosphor regions 340 may be arranged

in any desired pattern and function to convert the radiation emitted from the light source 310 into visible light. The transmissive body 330 may be coated with a reflective coating and outer paint layer, as described above, to prevent light from escaping from the transmissive body between the phosphor regions.

Figure 4 illustrates a decorative lighting apparatus according to another embodiment of the invention. The lighting apparatus 400 includes a plurality of light sources 410, 412, 414, a transmissive body 430, and a plurality of phosphor regions 440. The light sources 410, 412, 414 may comprise, for example, LEDs which emit light at different wavelengths, e.g. UV, blue, green, red. The light sources 410, 412, 414 may also emit the same wavelength. For example, three UV LEDs can be used so that the radiation emitted by the LEDs is invisible while the radiation emitted by the phosphor regions is visible.

The transmissive body 430 may be in the form of a thin sheet (e.g. having a thickness between 10^{-3} cm and 1 cm) as shown in Figure 4, or in any other shape. The phosphor regions 440 may be formed in any desired shape or pattern, such as the letters depicted in Figure 4, or other letters, numbers, pictures, patterns, and designs. Different phosphor regions, e.g. different words or letters in Figure 4, can comprise different phosphors such that they are caused to luminesce by only certain ones of the LEDs, and not by the other LEDs. For example, the first word "EAT" may comprise one or more phosphors which are activated only by the first LED 310, while the second word "AT" comprises one or more phosphors which are activated only by the second LED 312, etc. Illumination of the various phosphor regions can thus be controlled to occur at preselected times and in various combinations by activating the corresponding LEDs. As shown in Figure 4, a controller 450 can be utilized to activate the LEDs according to a desired schedule. The transmissive body 430 may also be coated with a reflective coating and outer paint layer, as described above, to prevent light from escaping from the transmissive body between the phosphor regions.

Other embodiments of the invention will be apparent to those skilled in the art from a consideration of the embodiments disclosed herein. For example, laser diodes and other light sources can be used in addition to LEDs. The transmissive body can be formed of various polymer or glass materials. A variety of patterns, shapes, sizes, and powers can be implemented as desired. The lighting apparatus can be sewn into clothing or used as jewelry or other adornments. In addition to providing a great variety of applications, exemplary embodiments of the invention can operate safely at a low power (e.g. less than one watt) over a long lifetime (e.g. tens of thousands of hours). It is intended that the specification and examples be considered as exemplary only, with the scope and spirit of the invention being defined by the following claims.

Claims

WHAT IS CLAIMED IS:

1. A lighting apparatus comprising

a light source;

a transmissive body optically coupled to the light source; and

at least one region of luminescent material formed on a portion of the transmissive body, the at least one region of luminescent material forming an ornamental design on the transmissive body, wherein the at least one region of luminescent material absorbs light having a first spectrum transmitted through the transmissive body and emits light having a second spectrum outside of the transmissive body.

2. The lighting apparatus of claim 1, wherein the at least one region of luminescent material comprises a phosphor.

3. The lighting apparatus of claim 1, wherein the at least one region of luminescent material is formed on an outside surface of the transmissive body.

4. The lighting apparatus of claim 1, further comprising a coating on a second portion of the transmissive body not occupied by the at least one region of luminescent material, which coating prevents light from escaping from the transmissive body.

5. The lighting apparatus of claim 4, wherein the coating comprises a reflective metal.

6. The lighting apparatus of claim 4, wherein the coating comprises a reflective multilayer dielectric film.

7. The lighting apparatus of claim 1, wherein the transmissive body includes at least one indentation upon which the at least one region of luminescent material is deposited.

8. The lighting apparatus of claim 1, wherein the transmissive body includes at least one roughened surface upon which the at least one region of luminescent material is deposited.

9. The lighting apparatus of claim 1, wherein the transmissive body comprises a fiber optic cable.

10. The lighting apparatus of claim 9, wherein the at least one region of luminescent material comprises a plurality of discrete regions of luminescent material which are distributed along the surface of the fiber optic cable.

11. The lighting apparatus of claim 9, wherein the fiber optic cable includes a splice region which scatters light outside of the transmissive body.

12. The lighting apparatus of claim 11, wherein the at least one region of luminescent material is sandwiched between two pieces of fiber optic cable in the splice region.

13. The lighting apparatus of claim 11, wherein the at least one region of luminescent material is formed on an outside surface of the fiber optic cable around the splice region.

14. The lighting apparatus of claim 1, wherein the transmissive body is in the form of a thin sheet, and the at least one region of luminescent material comprises a decorative pattern on the surface of the sheet.

15. The lighting apparatus of claim 1, wherein the transmissive body is in the form of a thin sheet, and the at least one region of luminescent material includes at least one of: letters of the alphabet and numbers.

16. The lighting apparatus of claim 1, wherein the transmissive body comprises at least one of a polymer, a silicone, and glass material.

17. The lighting apparatus of claim 1, wherein the transmissive body comprises a flexible material.

18. The lighting apparatus of claim 1, wherein the light source comprises a light emitting diode.

19. The lighting apparatus of claim 18, wherein the light emitting diode emits blue light.

20. The lighting apparatus of claim 18, wherein the light emitting diode emits ultraviolet radiation.

21. The lighting apparatus of claim 1, wherein the light source comprises a laser diode.

22. The lighting apparatus of claim 1, wherein the at least one region of luminescent material includes at least one of the following phosphors: $Y_3Al_5O_{12}$-Ce^{3+}; $Ba_2MgSi_2O_7$:Eu^{2+}; Ba_2SiO_4:Eu^{2+}; SrS:Eu^{2+}; SrY_2S_4:Eu^{2+}; $CaLa_2S_4$:Ce^{3+}; (Ca,Sr)S; and (Sr,Ca,Ba)$(Al,Ga)_2S_4$:Eu^{2+}.

23. The lighting apparatus of claim 1, wherein the at least one region of luminescent material includes at least one of the following phosphors: $(Sr,Ba,Ca)_5(PO_4)_3Cl$:Eu^{2+}; $BaMg_2Al_{16}O_{27}$:Eu^{2+}; $BaMgAl_{10}O_{17}$:Eu^{2+}; $Ca_8Mg(SiO_4)_4Cl_2$:Eu^{2+},Mn^{2+}; Ba_2SiO_4:Eu^{2+}; $Ba_2(Mg,Zn)Si_2O_7$:Eu^{2+}; $(Ba,Sr)Al_2O_4$:Eu^{2+}; and Y_2O_3:Bi^{3-},Eu^{3+}.

24. The lighting apparatus of claim 1, wherein the at least one region of luminescent material comprises a first region of luminescent material which emits a first spectrum and a second region of luminescent material which emits a second spectrum different from the first spectrum.

25. The lighting apparatus of claim 1, wherein the at least one region of luminescent material comprises a first region of luminescent material which emits red light and a second region of luminescent material which emits green light.

26. The lighting apparatus of claim 1, wherein the at least one region of luminescent material comprises phosphor blend which absorbs at least one of: blue light and UV radiation, and which emits white light.

27. The lighting apparatus of claim 1, wherein the light source comprises a first light emitting diode which emits a first spectrum and a second light emitting diode which emits a second spectrum different from the first spectrum.

28. The lighting apparatus of claim 27, wherein the at least one region of luminescent material comprises a first luminescent material responsive to radiation from the first light emitting diode, and a second luminescent material responsive to radiation from the second light emitting diode.

29. The lighting apparatus of claim 28, wherein the first luminescent material is substantially unresponsive to radiation from the second light emitting diode, and the second luminescent material is substantially unresponsive to radiation from the first light emitting diode.

30. The lighting apparatus of claim 1, further comprising a second transmissive body optically coupled to the light source.

31. The lighting apparatus of claim 1, wherein at least a portion of the at least one region of luminescent material is formed inside the transmissive body.

32. A decorative lighting apparatus comprising:

a first light source;

a second light source:

a transmissive body;

a first luminescent material formed on the transmissive body which is activated by the first light source;

a second luminescent material formed on the transmissive body which is activated by the second light source; and

a controller which activates the first and second light sources according to a predetermined schedule.

33. The lighting apparatus of claim 32, wherein the first and second luminescent materials produce an ornamental design.

34. The lighting apparatus of claim 33, wherein the first and second luminescent materials comprises first and second phosphors.

35. A method of making a lighting apparatus comprising the steps of:

optically coupling a light source to a transmissive body;

forming at least one region of luminescent material on the transmissive body, the at least one region of luminescent material having an ornamental design; and

generating light from the light source to activate the at least one region of luminescent material.

36. The method of claim 35, wherein:

the light source comprises at least one LED; and

the at least one region of luminescent material comprises a first phosphor region emitting a first color and a second phosphor region emitting a second color.

FIG. 1

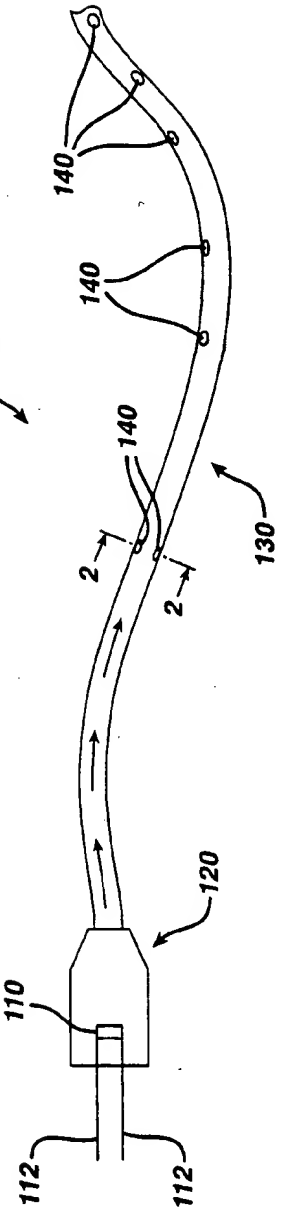


FIG. 2

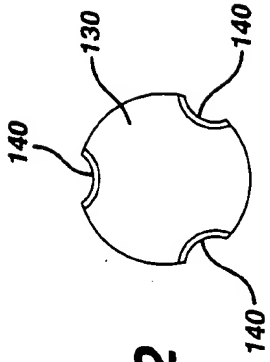


FIG. 3

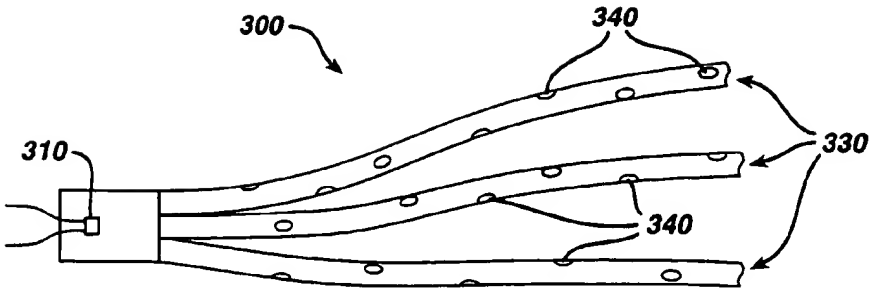
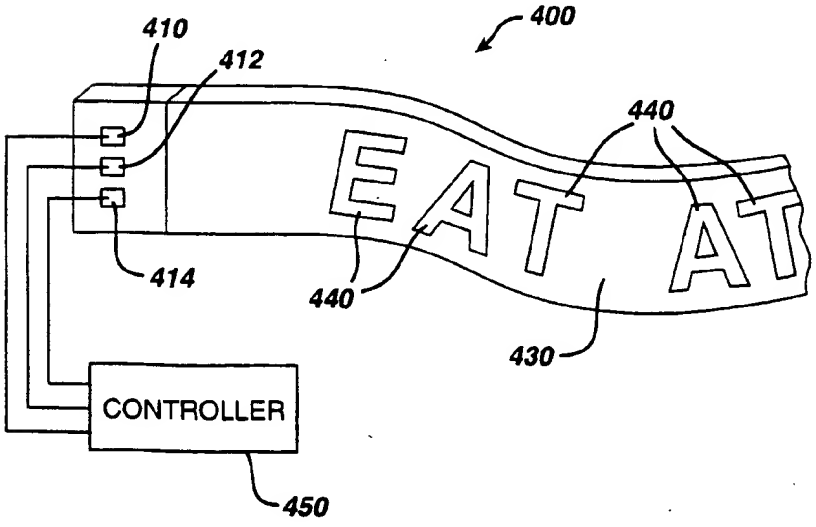

300
340
330
310
340

FIG. 4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INTERNATIONAL SEARCH REPORT

Inte al Application No
PCT/US 99/28435

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F21V8/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F21V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 92 09909 A (J.F.BECHELANI) 11 June 1992 (1992-06-11)	1,3,9, 10, 14-18, 24,25,35
Y A	the whole document	1,18-21 32
Y	US 5 813 753 A (L.VRIENS ET AL) 29 September 1998 (1998-09-29) cited in the application abstract; figures 1-5	18-20
Y	US 5 604 763 A (H.KATO ET AL.) 18 February 1997 (1997-02-18) cited in the application abstract; figure 1	21
	-/--	

[X] Further documents are listed in the continuation of box C. [X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
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"O" document referring to an oral disclosure, use, exhibition or other means
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 March 2000	23/03/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Malic, K

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INTERNATIONAL SEARCH REPORT

Inte ial Application No
PCT/US 99/28435

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	PATENT ABSTRACTS OF JAPAN vol. 10, no. 34 (P-427) '2091!, 8 February 1986 (1986-02-08) & JP 60 182402 A (MITSUBISHI JUKOGYO), 18 September 1985 (1985-09-18) abstract	1

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Int... nal Application No
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